Row Width and Weed Management Systems for Early Soybean Production System Plantings in the Midsouthern USA

Larry G. Heatherly,* Stan R. Spurlock, and C. Dennis Elmore

ABSTRACT

Management inputs that maximize economic return from the early soybean [*Glycine max* (L.) Merr.] production system (ESPS) in the midsouthern USA have not been evaluated fully. Field studies were conducted at Stoneville, MS (33°26′ N lat) to determine effect of weed management on yield and net return from maturity group (MG) IV and MG V cultivars grown in the ESPS in narrow rows (NRs; 50-cm width) and wide rows (WRs; 100-cm width) in nonirrigated (NI) and irrigated (IRR) environments. Use of NRs vs. WRs resulted in less weed cover at soybean maturity, but this was associated with greater weed management costs in NRs. In NI, choice of MG for ESPS plantings and choice of row width for MG V cultivars was arbitrary, but the MG IV cultivar did best in NR. Use of both pre-emergent (PRE) and postemergent (POST) broadleaf weed management in both NRs and WRs resulted in lower net returns. In IRR, NRs outyielded WRs, the MG IV cultivar yield equaled or exceeded the MG V yield in NRs, and the MG V cultivar outyielded the MG IV cultivar in WRs in both years. Differences in net returns followed yield differences. Use of POST-only broadleaf and grass weed management resulted in the highest net returns across the 2 yr. Thus, a MG IV cultivar planted in NRs with POST weed management appears to be the most profitable option in IRR-ESPS plantings. If WRs are required for management reasons in the ESPS, a MG V cultivar should be used.

The early soybean production system (ESPS: necessary seedbed preparation tillage in the fall; winter and spring weeds killed with a preplant, foliar-applied herbicide; early maturing cultivars planted into a stale, untilled seedbed in April; Heatherly, 1999c) vs. the conventional soybean production system (CSPS: May and June planting of later maturing cultivars) offers an alternative for soybean production in the midsouthern USA (Boquet, 1998; Bowers, 1995; Heatherly and Spurlock, 1999). The ESPS may utilize both indeterminate [maturity group (MG) III and IV] and determinate (MG V) cultivars (Bowers et al., 2000; Heatherly and Spurlock, 1999). Choice of row spacing in the ESPS should depend on the growth habit of indeterminate cultivars (Heatherly and Bowers, 1998) vs. determinate cultivars.

Soybean, especially that not irrigated, provides relatively low gross return with a small margin for profit in the midsouthern USA (Heatherly et al., 1994; Heatherly and Spurlock, 1999; Williams, 1999). The small profit margin from soybean grown without irrigation dictates that all costs associated with production must be minimized and that yield losses due to controllable pests such as weeds must be prevented within economic constraints. In previous research at Stoneville, where drought was common during the reproductive period of soybean, level of weed management in nonirrigated (NI) CSPS plantings was of little consequence when the weeds present were not highly competitive species (Heatherly et al., 1994). However, weed management expenditures are made early in the season before the onset of drought stress and without knowledge of the ensuing moisture status for subsequent crop and weed development.

Inputs used for weed management in soybean represent a significant cost (Buhler et al., 1997; Heatherly et al., 1994; Johnson et al., 1997) and must be managed early [pre-emergent (PRE)] or on an as-needed basis [postemergent (POST)]. In narrow-row (NR) soybean plantings, effective weed management systems will almost exclusively involve herbicides (Johnson et al., 1997, 1998; Oliver et al., 1993), but this can lead to improved weed control in NR systems that will result in greater yield and net returns than from wide-row (WR) systems (Mickelson and Renner, 1997; Swanton et al., 1998). Use of combinations of PRE and POST herbicides with POST cultivation for broadleaf and grass weed control is commonplace in WR-CSPS systems in the midsouthern USA (Askew et al., 1998; Heatherly et al., 1993, 1994; Hydrick and Shaw, 1995; Oliver et al., 1993; Poston et al., 1992).

Wide-row soybean production systems are used because they match the row-spacing requirements of other row crops in a producer's crop mix. Wide-row systems are amenable to band application of herbicides and POST cultivation, which may result in lower weed control costs. Narrow-row systems, on the other hand, preclude POST cultivation, which normally has been used in WRs (≥0.75 m) of the CSPS (Buhler et al., 1997; Hooker et al., 1997; Newsom and Shaw, 1996; Swanton et al., 1998). Bowers et al. (2000) determined that yields of MG III and MG IV indeterminate cultivars grown in NRs were greater than yields from WRs at 50% of the sites in a regional study (Arkansas, Louisiana, and Texas). However, weed control was essentially 100% in these studies, so the economic importance of yield responses could not be determined. Thus, determination of economically feasible weed management systems using broadcast-applied PRE and POST herbicides without POST cultivation in NRs and using band-applied PRE and POST herbicides with POST cultivation in WRs in the ESPS is necessary.

L.G. Heatherly, USDA-ARS, Crop Genet. and Prod. Res. Unit, P.O. Box 343, Stoneville, MS 38776; S.R. Spurlock, Dep. of Agric. Econ., P.O. Box 9755, Mississippi State, MS 39762; and C.D. Elmore, USDA-ARS Appl. and Prod. Technol. Res. Unit, P.O. Box 36, Stoneville, MS 38776. Received 9 Jan. 2001. *Corresponding author (lheatherly@ars.usda.gov).

Published in Agron. J. 94:1172–1180 (2002).

Abbreviations: CSPS, conventional soybean production system; ESPS, early soybean production system; IRR, irrigated; MG, maturity group; NI, nonirrigated; NR, narrow row; POST, postemergent; PRE, pre-emergent; RW, row width; WR, wide row; WTRT, weed management treatment.

Many weed management systems will provide similar control of weeds, but cost differences can be large (Buhler et al., 1997; Heatherly et al., 1993, 1994). This cost difference, coupled with differences in yield among weed management systems, can mean significant differences in net return among systems of weed control (Buhler et al., 1997; Heatherly et al., 1993, 1994; Johnson et al., 1997). Only analysis of the economic effect of yield differences coupled with the effect of differing costs among weed management systems in different row widths (RWs) can accurately determine which production system is more profitable.

Plantings using the ESPS are being made in fields previously cropped using the CSPS where weed control was excellent and subsequent weed pressure is low. Varying the RW for soybean is expected to affect weed pressure because of RW's effect on time of canopy closure. Combinations of row spacing and cultivar with varying weed management in continuous (year after year) ESPS plantings in the midsouthern USA have not been evaluated. The objective of this study was to determine the effect of PRE and POST weed management on weed cover in and seed yield from NI and irrigated (IRR) ESPS plantings of nontransgenic soybean cultivars grown in NRs (0.5 m wide) and WRs (1 m wide) and to evaluate this effect on yield in relation to cost of and net return from the various systems.

MATERIALS AND METHODS

Field studies were conducted in 1997 and 1998 at the Delta Research and Extension Center at Stoneville, MS (33°26′ N lat), on Sharkey clay (very fine, smectitic, thermic Chromic Epiaquert). Separate NI and IRR experiments were conducted using a randomized complete block design with four replicates each year. Treatments were arrayed in a split-split plot factorial arrangement with RW as the main plot, cultivar as the subplot, and weed management treatment (WTRT) as the sub-subplot. Treatments were randomly assigned to plots in 1997 and remained in the same location thereafter to assess the effect of continued use of a system.

Plantings were made on 8 Apr. 1997 and 1 Apr. 1998. A conventional plate planter with double-disk openers and closing wheels to seal the seed trench was used. Cultivars were Dixie 478 (MG IV, early maturing) and DP 3588 (MG V, later maturing), which were chosen based on yield history at the study site, regional variety trial results, and use patterns by producers. The MG IV cultivar has an indeterminate growth habit with upright stature and little branching. The MG V cultivar has a determinate growth habit with a bushy canopy structure resulting from branching up the entire length of the main stem. Seed were treated with mefenoxam [*N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl)-D-alanine methyl ester] fungicide at 0.11 g a.i. kg^{-1} seed before seeding.

Row widths were 0.5 m (NR) and 1 m (WR). Seeding rate was 16 seed m^{-1} NR and 33 seed m^{-1} WR, or about 50 kg ha^{-1} seed. Plots were 4 m (eight NRs or four WRs) wide and 21.5 m (IRR) or 30.5 m (NI) long in both years. All experiments were seeded into a stale seedbed (Heatherly and Elmore, 1983; Heatherly et al., 1993; Heatherly, 1999b) that had been tilled with a disk-harrow and/or a spring-tooth field cultivator in the fall. Glyphosate [*N*-(phosphonomethyl)glycine] at either 560 (1997) or 840 (1998) g a.i. ha^{-1} in 94 L ha^{-1} water was applied preplant to IRR in 1997 and to NI and IRR in 1998 to kill weed vegetation. Populations of emerged soybean plants were visually assessed to determine adequacy and uniformity within plots and among plots of different treatments. Random measurements were made after emergence each year, and stands were determined to be of acceptable density and uniformity in all plots.

Weed management treatments were selected along the following premises. First, uncontrolled weeds will reduce soybean yield. Therefore, no weedy check was included. Second, the inclusion of economic analyses in this study dictated that all WTRTs be practical and realistic. Also, there was no intent to determine how WTRT related to an economically unattainable or unfeasible weed-free environment. Therefore, a weed-free check was not included. Third, both PRE and POST broadleaf weed management may not be necessary, especially in WRs with POST cultivation. Fourth, cultivation in WRs was assumed to be a POST weed control measure that could be used in lieu of POST herbicides in a treatment with a POST component. Finally, the intent was to have weed management options that differ in cost. Broadcasting herbicides in NRs vs. banding herbicides along with supplemental POST cultivation in WRs is one way of doing this. Another way is to use PRE (based on expected weed infestations) vs. POST (based on actual weed infestations) herbicides in various combinations. Based on these premises, WTRTs were (i) PRE broadleaf and POST grass weed control, (ii) POST broadleaf and grass weed control, and (iii) PRE and POST broadleaf weed control and POST grass weed control. Weed management in NRs was done exclusively with herbicides, whereas both herbicides and POST cultivation were used in WRs. Postemergent cultivation was conducted in WRs three times in 1997 and two times in 1998. Within each WTRT, use of herbicides and their combinations in both NRs and WRs and use of cultivation in WRs was dictated by expected weed populations (PRE) or actual populations (POST). Selection of POST herbicides was based on expert opinion from assessing the presence and size of particular weed species in plots of each WTRT within each RW. The objective was to minimize weed competition within the constraints of each individual treatment.

Herbicides (see Table 1 for chemical notation) were broadcast-applied to NRs and band-applied (0.5-m-wide band centered over each row) to WRs each year at labeled rates with recommended adjuvants and in recommended tank mixes. Pre-emergent herbicides were applied immediately after planting each year. In 1997, rainfall did not occur until 14 d after PRE herbicide application, whereas 18.5 mm of rain fell 2 d after the PRE application in 1998. The 14-d period between the PRE treatment and rain in 1997 resulted in more intensive POST weed management in 1997 than in 1998 (see Table 1). Pre-emergent herbicides and POST broadleaf herbicides were applied in 187 L ha^{-1} water, whereas POST grass herbicides were applied in 94 L ha^{-1} water. Herbicides were applied using a canopied sprayer (Ginn et al., 1998a) for over-the-top applications (to prevent drift to adjacent plots of different treatments) or a directed sprayer (Ginn et al., 1998b) for applications underneath the developing soybean canopy. Herbicides and application rates were premix of metribuzin at 450 g a.i. ha^{-1} plus chlorimuron at 75 g a.i. ha^{-1} applied PRE, premix of bentazon at 560 g a.i. ha^{-1} plus acifluorfen at 280 g a.i. ha^{-1} applied POST, sethoxydim at 213 g a.i. ha^{-1} applied POST, fluazifop at 213 g a.i. ha^{-1} applied POST, and a tank mix of 2,4-DB at 224 g a.i. ha^{-1} plus linuron at 560 g a.i. ha^{-1} applied POST as a directed spray underneath the soybean canopy.

In the IRR experiments, water was applied by the furrow method through gated pipe whenever soil water potential at the 30-cm depth, as measured by tensiometers, decreased to

Table 1. Pre-emergent (PRE) and Postemergent (POST) herbicides applied to nonirrigated (NI) and irrigated (IRR) narrow-row (NR) and wide-row (WR) early soybean production system (ESPS) plantings at Stoneville, MS, 1997–1998. Herbicides applied to WR and/or NR are noted.

WTRT†	Herbicide‡
	1997 NI
1	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR).
2	POST bentazon + acifluorfen (NR); POST sethoxydim (NR); POST 2,4-DB + linuron (NR and WR).
3	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR); POST 2,4-DB + linuron (NR and WR).
	1998 NI
1	PRE metribuzin + chlorimuron (NR and WR).
2	POST bentazon + acifluorfen (NR and WR).
3	PRE metribuzin + chlorimuron (NR and WR); POST 2,4-DB + linuron (NR).
	1997 IRR
1	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR); POST fluazifop (WR).
2	POST sethoxydim (NR); POST bentazon + acifluorfen (NR); POST fluazifop (WR); POST 2,4-DB + linuron (NR and WR).
3	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR); POST fluazifop (WR); POST 2,4-DB + linuron (NR and WR).
	1998 IRR
1	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR and WR).
2	POST sethoxydim (NR and WR); POST bentazon + acifluorfen (NR and WR).
3	PRE metribuzin + chlorimuron (NR and WR); POST sethoxydim (NR and WR); POST bentazon + acifluorfen (NR and WR).

† WTRT, weed management treatment: (1) PRE broadleaf and POST grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

‡ + indicates either a premix or a tankmix; metribuzin, 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one; chlorimuron, 2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid; bentazon, 3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide; acifluorfen, 5-[2-chloro-4-trifluoromethyl)phenoxy]-2-nitrobenzoid acid; sethoxydim, 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; fluazifop {2-[4-]]5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid; 2,4-DB, 4-(2,4-dichlorophenoxy)butanoic acid; linuron, *N*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea.

about −70 kPa. The effect of irrigation on soybean yield in the midsouthern USA is well documented (Heatherly, 1999a), but irrigation environment can also affect infestation levels of some weed species in WR culture (Heatherly et al., 1994). Irrigation dates in 1997 were 27 June and 11, 21, and 31 July for both cultivars and 7 August for DP 3588. In 1998, irrigation was applied on 16 and 25 June and 2, 23, and 31 July to both cultivars and on 10 and 25 August to DP 3588. Applied water traversed the area in furrows created by the tractor wheels during seeding on this soft clay soil. Irrigation was started at or near beginning bloom and was continued until the full seed stage. Irrigation amounts were determined by the degree of cracking in this shrink-swell soil (cracks when dry and swells when wet) because water applied to it through surface irrigation flows downward to the depth of cracking and rises to the surface as the cracks fill (Mitchell and van Genuchten, 1993). Weather data in Table 2 were collected about 2 km from the experimental site by Delta Research and Extension Center personnel.

Total weed cover was determined (Elmore and Heatherly, 1988) after soybean leaf senescence (just before harvest) to measure the season-long effect of the WTRTs. Weed cover by species was estimated visually from five randomly chosen 0.5-m^2 sample areas in each plot. Estimates of weed cover in 10% increments from 0 to 100% were made to estimate cover for each weed species. If a species was present in any of the samples of an individual plot, then its relative abundance was

Table 2. Average daily maximum temperatures (Avg. T_{max}) and total rainfall amounts (rain) for indicated months during 1997 and 1998, and 30-yr normals at Stoneville, MS.

	1997		1998		30-yr normals†	
Month	Avg. T_{max}	Rain	Avg. T_{max}	Rain	Avg. T_{max}	Rain
	°C	mm	°C	mm	°C	mm
Apr.	20.5	114	23.5	110	23.5	137
May	26.5	148	30.5	117	28.0	127
June	30.5	106	33.5	40	32.0	94
July	34.5	74	34.5	145	33.0	94
Aug.	31.5	71	34.5	18	32.5	58

† 1964–1993; Boykin et al., 1995.

categorized as at least 0 to 10% (average of 5% cover) in that sample. This is similar to the process used by Yelverton and Coble (1991) to measure weed resurgence at the end of the growing season following early-season application of WTRTs intended to give 100% control.

Just before harvest each year, mature plant height (length from the soil surface to the tip of stem) was measured in all plots. Lodging ratings were recorded each year, but none exceeded a score of 1 (almost all plants erect). Thus, lodging data are not presented. A field combine modified for small plots was used to harvest the two (WR) or four (NR) center rows of each plot on 5 September (Dixie 478) and 22 September (DP 3588) in 1997 and on 27 August (Dixie 478) and 21 September (DP 3588) in 1998. Seed from all plots were cleaned by the harvesting machine; thus, correction for foreign matter content in seed of any treatment combination was not necessary in any year. Harvested seed were weighed and adjusted to 130 g moisture kg^{-1} seed.

Estimates of total expenses and returns were developed for each annual cycle of each experimental unit using the Mississippi State Budget Generator (Spurlock and Laughlin, 1992). Total specified expenses were calculated using actual inputs for each treatment in each year of the experiment and included all operating expenses and machinery ownership costs but excluded charges for land, management, and general farm overhead, which were assumed to be the same for all treatment combinations. Machinery ownership costs for tractors, self-propelled harvesters, implements, sprayers, and the irrigation system were estimated by computing the annual capital recovery charge for each machine and applying its per-hectare rate to each field operation. Operating expenses included those for herbicides and adjuvants, seed, rollout vinyl pipe used in irrigation, and labor; fuel, repair, and maintenance of machinery and irrigation systems; hauling harvested seed; and interest on operating capital. Planting expenses associated with NRs were \$4 to \$6 ha^{-1} greater than those for WRs and resulted from the difference in ownership costs of planters that is associated with the differing number of row units needed for a NR vs. WR planter. Weed management expenses after planting were calculated for each treatment and included charges for herbicides, surfactants, and application, plus POST cultivation in WRs. All application charges included both operating expenses and ownership costs associated with tractors and sprayers.

Costs for machinery and operating expenses were based on prices paid by Mississippi farmers each year. Irrigation expenses were based on a 65-ha furrow irrigation setup and included an annualized cost for the engine, well, pump, gearhead, generator, fuel tank and lines, and land leveling. Within the NI and IRR environments, expenses for both cultivars within a WTRT and year were essentially the same.

The USDA loan rate of \$0.196 kg^{-1} soybean for Mississippi was used to calculate income from each experimental unit each year and to assess break-even prices, which were calculated by dividing the total expense for each treatment combination by its yield. Net return above total specified expenses was determined for each experimental unit each year.

Analysis of variance [PROC MIXED (SAS Inst., 1996)] was used to evaluate the significance of treatment effects on weed cover, plant height, seed yield, and net return within the separate NI and IRR experiments. Analyses across years treated year as a fixed effect to determine interactions involving year. Analyses for individual years treated RW, cultivar, and WTRT as fixed effects. Mean separation was achieved with an $LSD_{0.05}$.

RESULTS AND DISCUSSION

Weather and Soybean Development

Thirty-year average monthly maximum air temperatures and total monthly rainfall for April through August (Boykin et al., 1995) at Stoneville and 1997 and 1998 averages for the same months are presented in Table 2. In 1997, average maximum air temperatures were near or below normal during all months of the growing season. Rainfall during the April through August period was near normal. The beginning pod through full seed period for Dixie 478 was 4 June to 18 August while the same period for DP 3588 was 21 June to 1 September. Thus, the moderate weather during these periods prevented significant drought stress. In 1998, monthly average maximum air temperatures were at or above normal during the April through August period. Rainfall amounts were below average in June and August. The shortage of rain in June was somewhat tempered by the fact that 95% of the May rain fell on 29 May. Most of the above-normal 145 mm of rainfall in July occurred before 15 July while rainfall for the remainder of July and all of August totaled only 18 mm. The beginning pod through full seed periods for Dixie 478 and DP 3588 were 29 June through 3 August and 27 July through 4 September, respectively. Thus, both cultivars were at critical reproductive stages during this drought period, but DP 3588 was most affected due to its later development. For comparison purposes, 1997 was considered a moderate year for weather while 1998 experienced heat and/or drought stress during some portion of the critical reproductive period of both cultivars. The MG IV cultivar matured in early August of each year, whereas the MG V cultivar matured in early September each year.

Nonirrigated

Plant Height

Row width, cultivar, and WTRT significantly affected plant height in both 1997 and 1998 (Table 3). In 1997, plants in NRs averaged 54 cm and those in WRs 50 cm; DP 3588 plants were an average 6 cm taller than Dixie 478 plants; and plants in WTRT 2 (POST-only weed management) averaged 6 cm or more taller than plants

Table 3. Mature plant height of maturity group (MG) IV and V soybean cultivars grown in row widths (RWs) of 0.5 m [narrow row (NR)] and 1.0 m [wide row (WR)] under varying weed management in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS, 1997–1998. Least significant differences ($LSD_{0.05}$)† for mean comparisons are presented in the footnotes.

Cultivar (MG)	WTRT‡	1997 NR	1997 WR	1997 Avg.	1998 NR	1998 WR	1998 Avg.
		cm					
			NI				
Dixie 478 (IV)	1	52	48	50	44	32	38
	2	54	50	52	70	68	69
	3	48	44	46	44	34	40
	Avg. of WTRT 1–3	51	47	49	53	45	49
DP 3588 (V)	1	53	49	51	44	42	43
	2	66	56	61	76	72	74
	3	53	52	52	47	44	45
	Avg. of WTRT 1–3	57	52	55	56	53	54
	Avg.	54	50	52	54	49	52
			IRR				
Dixie 478 (IV)	1	62	54	58	55	40	48
	2	72	54	63	62	55	58
	3	58	46	52	48	44	46
	Avg. of WTRT 1–3	64	51	58	55	46	51
DP 3588 (V)	1	80	60	70	76	51	63
	2	88	64	76	81	56	68
	3	82	56	69	75	50	62
	Avg. of WTRT 1–3	84	60	72	77	52	65
	Avg.	74	55	65	66	49	58

† 1997 NI: RW = 4, cultivar = 3, WTRT = 3; 1998 NI: RW × cultivar × WTRT = 5; 1997 IRR: WTRT = 4; RW × cultivar = 4; 1998 IRR: WTRT = 3; RW × cultivar = 3.

‡ WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

in the other WTRTs, which included PRE weed management. In 1998, the RW × cultivar × WTRT interaction was significant. For Dixie 478, plants in NRs were taller than those in WRs in WTRTs 1 and 3 while for DP 3588, NR and WR plants within a WTRT were not significantly different in height. Plants of DP 3588 were taller than those of Dixie 478 only in WR-WTRTs 1 and 3. Plants of both cultivars in WTRT 2 (POST-only weed management) were taller than those in WTRTs 1 and 3 (PRE weed management). Bowers et al. (2000) concluded that the effect of RW on plant height was inconsistent in NI-ESPS environments and not large enough to be agronomically important. In our study, RW had a relatively small and inconsistent effect on plant height.

Weed Management Expense and Weed Cover

Expense for weed management in each WTRT within each RW was the same for the two cultivars within each year. Therefore, expense associated with each WTRT is shown only for each RW (Table 4). Since each subsubunit received the same weed management across replicates, all differences in weed management expense are significant.

Weed management in NRs was more expensive than that in WRs in both years (Table 4). Thus, the banding of herbicides plus POST cultivation resulted in lower weed management expense, which concurs with results from previous research in conventional plantings (Buhler et al., 1997; Krausz et al., 1995; Heatherly et al., 2001). In 1997, weed management in NRs was the most expensive in WTRT 3 (PRE and POST broadleaf and POST grass weed management) and the least expensive in WTRT 1 (PRE broadleaf and POST grass weed management). In 1998, weed management in NRs was the most expensive in WTRT 3 (PRE and POST broadleaf plus POST grass weed management) and the least expensive in WTRT 2 (POST broadleaf and grass weed management). In WR, weed management in 1997 was the most expensive in WTRT 3 and the least expensive in WTRT 2 while in 1998, weed management expenses in all WTRTs were similar.

Weed cover at harvest was significantly affected by RW and cultivar in both years (Table 5). In 1997, average weed cover was greater in WRs (22%) than in NRs (9%) and in Dixie 478 (26%) than in DP 3588 (5%). More than half of the weed cover in all treatment combinations in 1997 was provided by browntop millet [*Brachiaria ramosa* (L.) Stapf]. In 1998, average percentage weed cover in WRs and Dixie 478 (9%) was greater than the 4% weed cover in NRs and DP 3588. Browntop millet and pitted morningglory (*Ipomoea lacunosa* L.) dominated. Thus, the taller cultivar and NRs resulted in less weed cover in both years.

Seed Yield and Net Return

In 1997, cultivar was the only main effect that significantly affected both yield and net return (Tables 6 and 7). There were no significant interactions. The 2185 kg ha^{-1} average yield (Table 6) and \$165 ha^{-1} average net return (Table 7) from DP 3588 exceeded the 1635 kg ha^{-1} and \$64 ha^{-1} from Dixie 478. The yield difference between cultivars was associated with the difference in weed cover between the two (Table 5). The 48 kg ha^{-1} spread in average yield and the \$44 ha^{-1} spread in average net return among WTRTs were too small to be significant.

In 1998, the RW, cultivar, and WTRT main effects significantly affected both yield and net return. However, the RW × cultivar and RW × WTRT interactions significantly affected both variables, and they will be discussed. In the RW × cultivar interaction involving yield, Dixie 478 outyielded DP 3588 in both NRs and WRs, but the difference between the two cultivars was greater in NRs (2345 vs. 1650 kg ha^{-1}) than in WRs (1700 vs. 1470 kg ha^{-1}). The difference in yield between NRs and WRs was also greater for Dixie 478. For the RW × WTRT interaction, average NR yields from WTRTs 1 and 3 (2040 and 1855 kg ha^{-1}, respectively) were greater than WR yields, whereas WTRT 2 yields in NRs and WRs (2095 and 2000 kg ha^{-1}, respectively) were similar. In WRs, average yield of 2000 kg ha^{-1} from WTRT 2 was greater than yield from the other treatments while in NR, average yield from WTRT 3

Table 4. Expenses for weed management (WEXP) and total expenses (TEXP†) for soybean grown in row widths of 0.5 m [narrow row (NR)] and 1.0 m [wide row (WR)] in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS, 1997–1998.

	1997						1998					
	NR		WR		Avg.		NR		WR		Avg.	
WTRT‡	WEXP	TEXP	WEXP	TEXP	WEXP	TEXP	WEXP	TEXP	WEXP	TEXP	WEXP	TEXP
	$/ha											
	NI											
1	91	267	54	222	72	245	58	301	45	280	52	291
2	120	296	47	213	83	254	40	283	41	281	41	282
3	139	317	76	246	108	282	100	345	45	280	73	313
Avg.	117	293	59	227	88	260	66	310	44	280	55	295
	IRR											
1	92	444	73	414	82	429	70	429	57	404	63	416
2	120	474	66	406	93	440	59	420	60	414	60	416
3	139	494	96	436	118	465	110	471	82	433	96	452
Avg.	117	471	78	419	98	445	80	440	66	417	73	428

† Includes all operating expenses and equipment ownership costs but excludes charges for land, management, and general farm overhead.
‡ WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

Table 5. Weed cover at harvest in maturity group (MG) IV and V soybean cultivars grown in row widths of 0.5 m [narrow row (NR)] and 1.0 m [wide row (WR)] under varying weed management in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS, 1997–1998. Least significant differences ($LSD_{0.05}$)† for mean comparisons are presented in the table footnotes.

		1997			1998		
Cultivar (MG)	WTRT‡	NR	WR	Avg.	NR	WR	Avg.
		%					
			NI				
Dixie 478 (IV)	1	18	36	27	10	14	12
	2	14	35	24	6	6	6
	3	17	34	26	2	14	8
	Avg. of WTRT 1–3	16	35	26	6	12	9
DP 3588 (V)	1	2	10	6	2	7	4
	2	1	7	4	0	5	3
	3	4	8	6	2	6	4
	Avg. of WTRT 1–3	2	8	5	1	6	4
	Avg.	9	22	16	4	9	6
			IRR				
Dixie 478 (IV)	1	28	54	41	53	87	70
	2	12	56	34	47	65	56
	3	32	76	54	61	84	73
	Avg. of WTRT 1–3	24	62	43	53	79	66
DP 3588 (V)	1	3	15	9	2	56	29
	2	4	13	8	13	17	15
	3	4	19	12	8	43	25
	Avg. of WTRT 1–3	4	16	10	8	39	23
	Avg.	14	39	26	30	59	45

† 1997 NI: RW = 8; cultivar = 8; 1998 NI: RW = 2; cultivar = 2; WTRT = 3; 1997 IRR: RW × cultivar = 9; cultivar × WTRT = 11; 1998 IRR: cultivar = 8; RW × WTRT = 14.

‡ WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

(PRE and POST broadleaf and POST grass weed management) was lower than yield from WTRT 2.

In the RW × cultivar interaction involving net return, higher average net return was received from Dixie 478 than from DP 3588 in both RWs, but the difference between the two was greater in NRs. Dixie 478 provided greater average return in NRs than in WRs while there was no difference between NR and WR returns using DP 3588. For the RW × WTRT interaction, NR net return from WTRT 1 was greater than net return from the same treatment in WRs while WTRTs 2 and 3 produced similar returns across RWs. In WRs, average net return of \$112 ha^{-1} from WTRT 2 was greater than return from the other treatments while in NRs, average net returns of \$100 and \$112 ha^{-1} from WTRTs 1 and 2, respectively, exceeded that from WTRT 3.

Table 6. Seed yield of early planted maturity group (MG) IV and V soybean cultivars grown in row widths of 0.5 m [narrow row (NR)] an 1.0 m [wide row (WR)] under varying weed management in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS, 1997–1998. Least significant differences ($LSD_{0.05}$)† for mean comparisons are presented in the footnotes.

		1997			1998			2-yr avg.	
Cultivar (MG)	WTRT‡	NR	WR	Avg.	NR	WR	Avg.	NR	WR
		kg ha^{-1}							
				NI					
Dixie 478 (IV)	1	1990	1545	1765	2460	1530	1995	2225	1535
	2	1735	1480	1605	2335	2070	2205	2035	1775
	3	1650	1405	1530	2235	1495	1865	1940	1450
	Avg. of WTRT 1–3	1790	1475	1635	2345	1700	2020	2065	1585
DP 3588 (V)	1	2205	2010	2110	1625	1200	1410	1915	1605
	2	2145	2200	2175	1850	1930	1890	1995	2065
	3	2175	2370	2270	1475	1280	1375	1825	1825
	Avg. of WTRT 1–3	2175	2195	2185	1650	1470	1560	1910	1830
	Avg.	1985	1835	1910	1995	1585	1790	1990	1710
				IRR					
Dixie 478 (IV)	1	4445	2605	3525	2660	1105	1885	3550	1855
	2	4625	2750	3685	3345	2290	2815	3985	2520
	3	4120	2330	3225	2675	1525	2100	3395	1925
	Avg. of WTRT 1–3	4395	2560	3480	2895	1640	2265	3645	2100
DP 3588 (V)	1	3915	3450	3680	2715	1785	2250	3315	2615
	2	3860	3635	3750	2775	2395	2585	3315	3015
	3	3955	3365	3660	2720	1865	2295	3335	2615
	Avg. of WTRT 1–3	3910	3485	3695	2735	2015	2375	3320	2750
	Avg.	4155	3020	3590	2815	1830	2320	3485	2425

† 1997 NI: cultivar = 245; 1998 NI: RW × cultivar = 175; RW × WTRT = 215; 1997 IRR: WTRT = 200; RW × cultivar = 275; 1998 IRR: WTRT = 290; RW × cultivar = 335.

‡ WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

Table 7. Net return† from early planted maturity group (MG) IV and V soybean cultivars grown in row widths of 0.5 m [narrow row (NR)] and 1.0 m [wide row (WR)] under varying weed management in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS, 1997–1998. Least significant differences ($LSD_{0.05}$)‡ for mean comparisons are presented at the end of the table.

		1997			1998			2-yr avg.	
Cultivar (MG)	WTRT§	NR	WR	Avg.	NR	WR	Avg.	NR	WR
		$ ha^{-1}							
				NI					
Dixie 478 (IV)	1	127	84	106	179	19	99	153	52
	2	48	82	65	175	126	150	111	104
	3	10	35	23	92	13	52	51	24
	Avg. of WTRT 1–3	62	67	64	149	53	101	105	60
DP 3588 (V)	1	164	169	166	20	−44	−12	92	63
	2	123	216	169	82	98	90	102	157
	3	107	214	161	−54	−28	−41	27	93
	Avg. of WTRT 1–3	131	200	165	16	9	12	74	104
	Avg.	96	133	115	82	31	57	89	82
				IRR					
Dixie 478 (IV)	1	434	105	269	101	−178	−38	268	−36
	2	438	142	290	243	43	143	340	92
	3	320	29	175	62	−125	−32	191	−48
	Avg. of WTRT 1–3	397	92	245	135	−87	24	266	3
DP 3588 (V)	1	322	256	289	98	−62	18	210	97
	2	282	301	292	120	50	85	201	176
	3	278	216	247	56	−74	−9	167	71
	Avg. of WTRT 1–3	294	258	276	92	−29	31	193	114
	Avg.	346	175	260	113	−58	28	230	58

† Net returns calculated as difference between income [yield × price ($0.196 kg^{-1} loan rate for Mississippi)] and all operating expenses and ownership costs (excluding charges for land, management, and general farm overhead).

‡ 1997 NI: cultivar = 47; 1998 NI: RW × cultivar = 33; RW × WTRT = 41; 1997 IRR: RW × cultivar = 53; WTRT = 38; 1998 IRR: RW × cultivar = 64; WTRT = 55.

§ WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

Conclusions for No Irrigation

Use of NRs, a MG V cultivar, and POST-only weed management resulted in significantly taller plants. Use of NRs vs. WRs resulted in better weed control as indicated by less weed cover in NRs at soybean maturity, but this was associated with greater weed management expense in NRs. Others have reported varying degrees of enhanced weed control in NRs vs. WRs (Mickelson and Renner, 1997; Nelson and Renner, 1998). Seed yield from NRs was greater than that from WRs in 1 of the 2 yr, whereas net return from NRs was greater than that from WRs only with Dixie 478 in 1998. Net return from DP 3588 was greater than that from Dixie 478 in 1997 while the opposite was true in 1998. These contrasting differences in net returns between cultivars resulted from the different weather patterns of the 2 yr. Thus, choice of MG for ESPS plantings and choice of RW for MG V cultivars in ESPS plantings that are not irrigated appears arbitrary, but MG IV cultivars in ESPS plantings should be in NRs. Use of both PRE and POST broadleaf weed management in both NRs and WRs resulted in lower net returns because of greater weed management expense with no concurrent yield enhancement.

Irrigated

Plant Height

In 1997 and 1998, average height of plants in NRs was greater than that of plants in WRs, and average height of DP 3588 plants was greater than height of Dixie 478 plants (Table 3). However, the difference in average height between NRs and WRs was greater for DP 3588 (84 vs. 60 cm in 1997 and 77 vs. 52 cm in 1998) than for Dixie 478 (64 vs. 51 cm in 1997 and 55 vs. 46 cm in 1998). In 1997, the 70-cm average plant height in WTRT 2 (POST-only weed management) was greater than average plant height of the other WTRTs (all received PRE herbicides) while in 1998, WTRT 2 average height of 63 cm was greater than the 56- and 54-cm average height of plants in WTRTs 1 and 3, respectively. The magnitude of difference in plant height between NRs and WRs in these IRR plantings was larger than that between NRs and WRs in NI plantings, and such large differences are assumed to be agronomically significant in canopy formation.

Weed Management Expense and Weed Cover

Expense for each WTRT within each RW was the same for the two cultivars within each year. Therefore, expense associated with each WTRT is shown only for each RW (Table 4). Because each sub-subunit received the same weed management across replicates, all differences in weed management expense are significant.

Weed management in NRs was more expensive than that in WRs in both years (Table 4). Thus, the banding of herbicides plus POST cultivation resulted in less expense for WRs. As stated earlier, this is a common finding when economic comparisons are made between NR and WR systems. In both years, weed management in WTRT 3 (PRE and POST broadleaf and POST grass weed management) was the most expensive.

Weed cover at harvest was significantly affected by RW, cultivar, and WTRT each year (Table 5). In 1997, the RW × cultivar and cultivar × WTRT interactions were significant. Weed cover in WRs of both cultivars was greater, but the difference between WRs and NRs of Dixie 478 (62 vs. 24%) was greater than the difference between WRs and NRs of DP 3588 (16 vs. 4%). With Dixie 478, WTRT 1 (PRE broadleaf and POST grass weed management) and WTRT 2 (POST broadleaf and grass weed management) had less weed cover than did WTRT 3 (PRE plus POST broadleaf and POST grass weed management) while with DP 3588, weed cover differences among WTRTs were not significant. Annual grasses {browntop millet and red sprangletop [*Leptochloa filiformis* (L.) Beauv.]} were dominant.

In 1998, average weed cover in Dixie 478 (66%) was greater than the 23% average cover in DP 3588. The RW × WTRT interaction was significant. Within NRs, differences in weed cover among WTRTs were not significant while in WRs, average weed cover in WTRT 2 (41%) was lowest. Browntop millet was the dominant weed in all WR treatment combinations while NR treatment combinations contained mixes of browntop millet, ivyleaf morningglory [*I. hederacea* (L.) Jacq.], pitted morningglory, and johnsongrass [*Sorghum halepense* (L.) Pers.]. Essentially the only adequate weed control through maturity in 1998 resulted from use of DP 3588 in NRs or in WRs with WTRT 2.

All WTRTs resulted in excellent weed control at the end of the weed control period each year (before irrigation). These results indicate that late-season weed infestations were more problematic with the shorter indeterminate Dixie 478, especially in the WR environment where the final soybean canopy was incomplete and soil moisture from irrigation during reproductive development enhanced weed growth through the incomplete canopy. Weed cover was greater in WRs regardless of weed management. Nelson and Renner (1998) and Swanton et al. (1998) reported that weed control by herbicide treatments in studies using conventional plantings conducted at more northern latitudes (Michigan and Ontario) was enhanced in 19- vs. 75-cm WRs.

Seed Yield and Net Return

The WTRT main effect and the RW × cultivar interaction significantly affected yield and net return in both 1997 and 1998. In 1997, average yield (3720 kg ha^{-1}) and net return (\$291 ha^{-1}) from WTRT 2 were greater than average yield and return from WTRT 3 and statistically equal to average yield and return from WTRT 1 (Tables 6 and 7). In 1998, WTRT 2 average yield (2700 kg ha^{-1}) and net return (\$114 ha^{-1}) exceeded average yields and returns from WTRTs 1 and 3. Thus, use of POST-only weed management resulted in yields and net returns that were as good as or greater than those resulting from use of weed management that included PRE herbicides in both years.

For the RW × cultivar interaction, both cultivars in NRs outyielded their WR counterparts in both years. In NRs in 1997, Dixie 478 (4395 kg ha^{-1}) outyielded DP 3588 (3910 kg ha^{-1}) while in WRs, the opposite was true. In NRs in 1998, average yields of Dixie 478 (2895 kg ha^{-1}) and DP 3588 (2735 kg ha^{-1}) were not different while in WRs, DP 3588 outyielded Dixie 478. Thus, in both years, both cultivars grown in NRs outyielded their WR counterparts; Dixie 478 yielded as much as or more than DP 3588 in NRs; and DP 3588 outyielded Dixie 478 in WRs. In 1997, net return from Dixie 478 in NRs exceeded that from DP 3588 in NRs, whereas the opposite was true for WRs. The same trend occurred in 1998. Net returns to all cultivar–WTRT treatment combinations in 1998 were low or negative.

Conclusions for Irrigated

Use of NRs, a MG V cultivar, and POST-only weed management resulted in taller plants. Use of NRs vs. WRs and DP 3588 vs. Dixie 478 resulted in much better weed control as indicated by weed cover differences at soybean maturity (Table 5). Expenses for NR weed management were greater than those for WR weed management. In both years, NRs outyielded WRs; MG IV Dixie 478 yielded as much as or more than MG V DP 3588 in NRs; and DP 3588 outyielded Dixie 478 in WRs. Differences in net returns followed yield differences. Use of POST-only broadleaf and grass weed management (WTRT 2) resulted in the lowest weed management expense–highest net return combination across the 2 yr. These results indicate that a MG IV cultivar planted in NRs with POST-only weed management appears to be the most profitable option in an IRR-ESPS planting. If WRs are required for management reasons in an ESPS, MG V cultivars should be used.

OVERALL CONCLUSIONS

Using data averaged over the 2 yr of the study, lowest break-even prices for Dixie 478 grown in NRs occurred with WTRTs 1 and 2 while the lowest break-even price for Dixie 478 grown in WRs occurred in WTRT 2 (Table 8). For DP 3588 grown in both RWs, lowest break-even price occurred with WTRT 2. Yields of Dixie 478 in WRs in 1998 were below those necessary to cover expenses in WTRTs 1 and 3. All other treatment combinations produced yields that exceeded the break-even level. In all cases, the highest break-even yields occurred with WTRT 3. Break-even yields for WTRTs 1 and 2 were similar in all cases. Break-even prices for NRs were usually lower than those for WRs, and break-even yields for NRs were always higher than those for WRs.

In these ESPS plantings, use of NRs, a MG V cultivar, and POST-only weed management resulted in slightly but significantly taller plants in both NI and IRR environments. Use of NRs vs. WRs resulted in better weed control as indicated by less weed cover in NRs at soybean maturity, but this was associated with greater weed management expense in NRs in both NI and IRR. Use of POST-only weed management (WTRT 2) consistently resulted in the lowest expense combined with the highest net return in both NI and IRR. These results indicate that both MG IV and MG V cultivars planted using the ESPS should be in NRs, and POST-only weed management should be used for optimum agronomic and economic results.

Table 8. Break-even prices and yields (excluding charges for land, management, and general farm overhead) for early planted maturity group (MG) IV and V soybean cultivars grown in row widths of 0.5 m [narrow row (NR)] and 1.0 m [wide row (WR)] under varying weed management in nonirrigated (NI) and irrigated (IRR) environments at Stoneville, MS. Average of 1997 and 1998.

		Break-even prices		Break-even yields	
Cultivar (MG)	WTRT†	NR	WR	NR	WR
		$ $ kg^{-1}$		kg ha^{-1}	
		NI			
Dixie 478 (IV)	1	0.140	0.164	1450	1275
	2	0.150	0.141	1475	1250
	3	0.176	0.183	1685	1330
DP 3588 (V)	1	0.155	0.175	1450	1280
	2	0.150	0.123	1480	1270
	3	0.194	0.164	1695	1355
		IRR			
Dixie 478 (IV)	1	0.131	0.267‡	2200	2045‡
	2	0.114	0.165	2260	2050
	3	0.150	0.239‡	2430	2175‡
DP 3588 (V)	1	0.137	0.187	2250	2130
	2	0.138	0.146	2300	2130
	3	0.151	0.189	2490	2260

† WTRT, weed management treatment: (1) pre-emergent (PRE) broadleaf and postemergent (POST) grass weed control, (2) POST broadleaf and grass weed control, and (3) PRE and POST broadleaf and POST grass weed control.

‡ Denotes situations where break-even price (total expense divided by yield) is above the $0.196 kg^{-1} loan rate for Mississippi and yield from treatment combinations in the study is below the break-even yield (total expense divided by the $0.196 kg^{-1} loan rate) needed to cover all expenses, except charges for land, management, and general farm overhead.

ACKNOWLEDGMENTS

The authors appreciate the technical assistance provided by Lawrence Ginn, Sandra Mosley, and John Black; resources provided by the Delta Research and Extension Center; and supplemental funding provided by the United Soybean Board and the Mississippi Soybean Promotion Board.

REFERENCES

Askew, S.D., J.E. Street, and D.R. Shaw. 1998. Herbicide programs for red rice (*Oryza sativa*) control in soybean (*Glycine max*). Weed Technol. 12:103–107.

Boquet, D.J. 1998. Yield and risk utilizing short-season soybean production in the mid-southern USA. Crop Sci. 38:1004–1011.

Bowers, G.R. 1995. An early soybean production system for drought avoidance. J. Prod. Agric. 8:112–119.

Bowers, G.R., J.L. Rabb, L.O. Ashlock, and J.B. Santini. 2000. Row spacing in the early soybean production system. Agron. J. 92:524–531.

Boykin, D.L., R.R. Carle, C.D. Ranney, and R. Shanklin. 1995. Weather data summary for 1964–1993, Stoneville, MS. MAFES Tech. Bull. 201. Mississippi Agric. and Forestry Exp. Stn., Mississippi State.

Buhler, D.D., R.P. King, S.M. Swinton, J.L. Gunsolus, and F. Forcella. 1997. Field evaluation of a bioeconomic model for weed management in soybean (*Glycine max*). Weed Sci. 45:158–165.

Elmore, C.D., and L.G. Heatherly. 1988. Planting system and weed control effects on soybean grown on clay soil. Agron. J. 80:818–821.

Ginn, L.H., E.R. Adams, L.G. Heatherly, and R.A. Wesley. 1998a. A canopied sprayer for accurate application of herbicides. Agron. J. 90:109–112.

Ginn, L.H., L.G. Heatherly, E.R. Adams, and R.A. Wesley. 1998b. A sprayer for under-canopy application of herbicide sprays. J. Prod. Agric. 11:196–199.

Heatherly, L.G. 1999a. Soybean irrigation. p. 119–142. *In* L.G. Heatherly and H.F. Hodges (ed.) Soybean production in the Midsouth. CRC Press, Boca Raton, FL.

Heatherly, L.G. 1999b. The stale seedbed planting system. p. 93–102. *In* L.G. Heatherly and H.F. Hodges (ed.) Soybean production in the Midsouth. CRC Press, Boca Raton, FL.

Heatherly, L.G. 1999c. Early soybean production system (ESPS). p. 103–118. *In* L.G. Heatherly and H.F. Hodges (ed.) Soybean production in the Midsouth. CRC Press, Boca Raton, FL.

Heatherly, L.G., and G.R. Bowers. 1998. Early soybean production system handbook. USB 6009-091998-11000. United Soybean Board, St. Louis, MO.

Heatherly, L.G., and C.D. Elmore. 1983. Response of soybeans to planting in untilled, weedy seedbed on clay soil. Weed Sci. 31:93–99.

Heatherly, L.G., C.D. Elmore, and S.R. Spurlock. 1994. Effect of irrigation and weed control treatment on yield and net return from soybean (*Glycine max*). Weed Technol. 8:69–76.

Heatherly, L.G., C.D. Elmore, and S.R. Spurlock. 2001. Row width and weed management systems for conventional soybean plantings in the midsouthern USA. Agron. J. 93:1210–1220.

Heatherly, L.G., and S.R. Spurlock. 1999. Yield and economics of traditional and early soybean production system (ESPS) seedings in the midsouthern USA. Field Crops Res. 63:35–45.

Heatherly, L.G., R.A. Wesley, C.D. Elmore, and S.R. Spurlock. 1993. Net returns from stale seedbed plantings of soybean (*Glycine max*) on clay soil. Weed Technol. 7:972–980.

Hooker, D.C., T.J. Vyn, and C.J. Swanton. 1997. Effectiveness of soil-applied herbicides with mechanical weed control for conservation tillage systems in soybean. Agron. J. 89:579–587.

Hydrick, D.E., and D.R. Shaw. 1995. Non-selective and selective herbicide combinations in stale seedbed soybean (*Glycine max*). Weed Technol. 9:158–165.

Johnson, W.G., J.S. Dilbeck, M.S. DeFelice, and J.A. Kendig. 1998. Weed control with reduced rates of chlorimuron plus metribuzin and imazethapyr in no-till narrow-row soybean (*Glycine max*). Weed Technol. 12:32–36.

Johnson, W.G., J.A. Kendig, R.E. Massey, M.S. DeFelice, and C.D. Becker. 1997. Weed control and economic returns with postemergence herbicides in narrow-row soybeans. Weed Technol. 11:453–459.

Krausz, R.F., G. Kapusta, and J.L. Matthews. 1995. Evaluation of band vs. broadcast herbicide applications in corn and soybean. J. Prod. Agric. 8:380–384.

Mickelson, J.A., and K.A. Renner. 1997. Weed control using reduced rates of postemergence herbicides in narrow and wide row soybean. J. Prod. Agric. 10:431–437.

Mitchell, A.R., and M.Th. van Genuchten. 1993. Flood irrigation of a cracked soil. Soil Sci. Soc. Am. J. 57:490–497.

Nelson, K.A., and K.A. Renner. 1998. Weed control in wide- and narrow-row soybean (*Glycine max*) with imazamox, imazethapyr, and CGA-277476 plus quizalofop. Weed Technol. 12:137–144.

Newsom, L.J., and D.R. Shaw. 1996. Cultivation enhances weed control in soybean (*Glycine max*) with AC 263,222. Weed Technol. 10:502–507.

Oliver, L.R., T.E. Klingaman, M. McClelland, and R.C. Bozsa. 1993. Herbicide systems in stale seedbed soybean (*Glycine max*) production. Weed Technol. 7:816–823.

Poston, D.H., E.C. Murdock, and J.E. Toler. 1992. Cost-efficient weed control in soybean (*Glycine max*) with cultivation and banded herbicide application. Weed Technol. 6:990–995.

SAS Institute. 1996. SAS system for mixed models. SAS Inst., Cary, NC.

Spurlock, S.R., and D.H. Laughlin. 1992. Mississippi State Budget Generator user's guide version 3.0. Agric. Econ. Tech. Publ. 88. Mississippi State Univ., Mississippi State.

Swanton, C.J., T.J. Vyn, K. Chandler, and A. Shrestha. 1998. Weed management strategies for no-till soybean (*Glycine max*) grown on clay soils. Weed Technol. 12:660–669.

Williams, B. 1999. Economics of soybean production in Mississippi. p. 1–17. *In* L.G. Heatherly and H.F. Hodges (ed.) Soybean production in the Midsouth. CRC Press, Boca Raton, FL.

Yelverton, F.H., and H.D. Coble. 1991. Narrow row spacing and canopy formation reduces weed resurgence in soybeans (*Glycine max*). Weed Technol. 5:169–174.